Present status of the Cryogenic Dark Matter Search (CDMS II) Experiment

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Abstract

The CDMS experiment utilizes Ge and Si detectors operating at 20 mK to search for the Dark Matter of the Universe hypothesized to exist in the form of WIMPs (Weakly Interacting Massive Particles). In early 2000, CDMS set the most competitive exclusion limit for scalar-interaction WIMPs. A new search (CDMS II) is now commencing with several improvements: a deep-site facility in the Soudan mine, Minnesota; and the detector technology has been further improved to aid in the rejection of surface-electron (β) events. A new generation of detectors, sensitive to the initial athermal phonon flux from a particle event, have been in operation for the past year at Stanford's shallow site and are ready for installation at the deep site.

Key words: Dark Matter; particle detectors; calorimeters; neutrons

1. Introduction

The Cryogenic Dark Matter Search (CDMS) experiment utilizes Si and Ge detectors operated at 20 mK in its search for the hypothesized Weakly Interacting Massive Particles (WIMPS). These particles are motivated by extensions of the Standard Model of Particle Physics to account for cosmological constraints that suggest that a third of the Universe's critical density is in the form of WIMP-like Dark Matter[1,2].

In early 2000 the CDMS experiment set the most competitive exclusion limit for the existence of (scalar-interacting) WIMPS[1,2]. Concurrently, CDMS II was funded to operate more sophisticated detectors

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(ZIPs)[3] at a deeper underground site (Soudan, Minnesota). Significant competitors to CDMS include EDELWEISS[4] and CRESST[5].

The design philosophy of the CDMS experiment is to utilize particle detectors which have an ability to discriminate, on an event by event basis, between electron and nuclear recoils. The dominant natural radioactive background is in the form of gammas which generate electron recoil events in the detectors; whereas the WIMP signature of interest will be a nuclear recoil event. Our detectors[1–3] simultaneously measure the ionization (e-h pairs) and phonons produced by a particle interaction. Nuclear recoils (due to WIMPS or neutrons) result in only approximately 10% of the recoil energy going into ionization, whereas for the electron-recoil events approximately 30% of the energy enters the ionization system.

In addition, surface-electron events (βs) impinging the detector surface have little penetrating power and are problematic in that our detectors possess a thin 'dead-layer' in which the ionization collection efficiency from these electron-recoil events is reduced. Thus we introduced an amorphous-Si layer into the collection electrode structure[1] to reduce the dead-layer thickness, and we have changed the phonon sensor technology for CDMS II to one based upon Transition Edge Sensors (TESs) connected to superconducting Al collection fins that is only sensitive to athermal phonons[3].

2. Experiment Status

For the past year we have been operating six of these new 'ZIP' detectors in a stacked configuration (Tower 1) in the SUF icebox[3]. The discrimination ability of these 4 Ge and 2 Si detectors against gammas exceeds our requirements for the deep-site. Figure 1 shows the response of one of the Ge detectors to irradiation by an external Co-60 source.

Together, these 4 Ge and 2 Si detectors have detected 18 single-scatter nuclear-recoil events in the Ge, 2 single-scatter in the Si, and 9 multiply-scattered scattered events between the detectors over $\simeq$ 50 livedays running at SUF. The presence of any events in the Si detectors, and the multiply scattered events, indicates that the nuclear-recoil events detected are more likely to be neutrons than WIMPs. Monte Carlo modelling of the expected neutron background at SUF anticoincident with the muon veto shield gives 3 single-scatter events in the Si and 8 multiply-scattered events, for the same number of Ge single scatter events observed. Thus the results at SUF are consistent with the entire WIMP signal being due to the un-reducible external neutron background present at this shallow site. An accurate calculation of the corresponding (90% CL) WIMP exclusion limit is on-going, and further data taking at SUF is continuing.

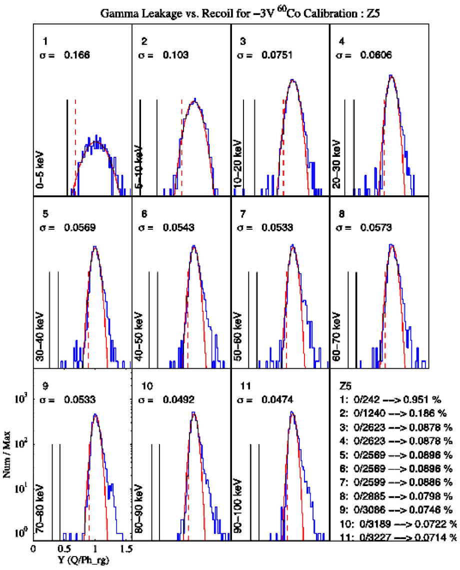

Fig. 1. Histogrammed yield parameter (Y) as a function of slices in recoil energy for events in a Ge ZIP detector due to an external Co-60 calibration source. Electron-recoil events are calibrated to be centered with a value of $Y \simeq 1$; the two closely space solid vertical lines indicate the 2σ acceptance band for nuclear recoils established with neutron source calibrations (not shown). The 'leakage' of gamma events into the nuclear recoil band, of interest in setting a Dark Matter limit, is impressively low: the limited exposure only allowing upper poissonian limits to be set for most of the (numbered) energy slices. Overall, 99.99% of gammas are rejected (at 90% CL) between 5 - 100 keV; with a rejection factor of 99.8% for the lowest energy slice (5 - 10 keV) considered.

Commissioning of the deep-site facility at the Soudan mine has been challenging. The cryogenic operation of the dilution refrigerator with attached ice-box is the next major mile-stone that needs to be accomplished. Once operational, the stack of detectors from SUF (Tower 1) will be installed at Soudan, possibly with an additional stack (Tower 2) that is close to completion of its testing program.

Once operational, we anticipate that our ultimate sensitivity at the Soudan site would allow us to exclude WIMP-nucleon cross-sections down to $\simeq 10^{-44}\text{cm}^2$ for a WIMP mass of 50 - 100 GeV/c^2.

References

[1] R. Abusadai, *et al*, Phys. Rev. Lett. **84** (2000) 5699.

[2] D. Abrams, *et al*, Phys. Rev. D (2002) in press.

[3] T. Saab, *et al*, AIP Conf. Proceed. **605** (2002) 497.

[4] X-F. Navick, *et al*, AIP Conf. Proceed. **605** (2002) 489.

[5] C. Cozzini, *et al*, AIP Conf. Proceed. **605** (2002) 481.